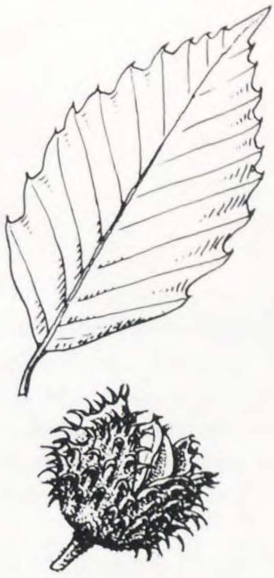
Silvical Characteristics of Beech

(Fagus grandifolia)

by Francis M. Rushmore



STATION PAPER NO. 161 • NORTHEASTERN FOREST EXPERIMENT STATION • 1961
FOREST SERVICE • U.S. DEPARTMENT OF AGRICULTURE • UPPER DARBY, PA.
RALPH W. MARQUIS, DIRECTOR

Preface

MUCH of the silvical information on our forest trees is widely scattered and sometimes difficult to find. To make this material more readily available, the Forest Service is assembling information on the silvical characteristics of all the important native forest tree species of the United States. It is expected that this information will be published as a comprehensive silvics manual.

This report presents the silvical characteristics of one species. It contains the essential information that will appear in the general manual but has been written with particular reference to the species in the Northeast. Similar reports on other species are being prepared by this Experiment Station and by several of the other regional forest experiment stations.

Silvical Characteristics of Beech

by Francis M. Rushmore

About the Author ...

FRANCIS M. RUSHMORE, *a graduate of the Forestry School of Pennsylvania State College, joined the staff of the Northeastern Forest Experiment Station in 1946 after nearly 5 years service with the U. S. Army. He was engaged for a while in forest economics research, and served at Station research units in Cooperstown, New York, and Laurel, Maryland. For the past 11 years he has served at the Station's Adirondack Research Center at Paul Smiths, New York, where he engaged in forest-management and silviculture research, including considerable exploratory work in use of silvicides. He served as leader of the Adirondack research unit from 1954 to June 1961, when the research center was discontinued. He is now stationed at the Bangor Research Center in Maine, where he is engaged in recreation research.*

The American Beech

OF ALL the trees in our forests, the beech somehow always stands out. Its clean, smooth, sculptured blending of bole and branch gives it a form that is unique. Also unique is its smooth gray bark, which does not become furrowed with old age as that of other trees, but remains smooth from ground to crown.

It is from the character of its bark that the beech tree takes its name. It was probably on beech bark that the first European literature was written. Virgil wrote: "Or shall I rather the sad verse repeat / Which on the beech's bark I lately writ." In the Teutonic languages the words beech and book are closely related. (In Swedish the word *bok* means both book and beech. In German the words for the two differ slightly: das *Buch* and die *Buche*.) In fact, *beech* is one word that in some form is common to all the Indo-European languages.

The beech tree is one that has had special meaning for man since man's beginnings. It is fairly certain that Stone Age man used the sweet, oily nuts of the beech tree for food. The tree has a prominent place in mythology and folklore. And in Europe the beech has long been a favored utility wood—for fuel, handles, tools, implements, furniture, wooden shoes, and many other uses.

Young as American folklore is, it also has found a place for the beech tree. One famous American beech tree, on the old stage road between Blountsville and Jonesboro, Tennessee, recorded this folk history on its bark:

D. Boone
Cilled A Bar
On Tree
In Year 1760

The scars of the carving were still visible when the tree fell in 1916, at an estimated age of 365 years. The smooth bark of

Figure 1.—The smooth gray bark of the beech tree invites the carving of initials. The word beech is closely related to the word book.

the beech almost invites one to carve initials on it (fig. 1). Once the bark is carved, the mark endures for the life of the tree.

The mast of beech nuts was the favorite food of the now-extinct passenger pigeon. James Audubon wrote that the migrations of the great flocks seemed to be mainly a quest for the harvest of beech nuts. When he painted a picture of a pair of passenger pigeons, it was on a beech bough that he perched them.

The American beech (*Fagus grandifolia Ehrh.*) is the only native species of this genus in the United States, and in the older literature it is listed as the only American species (*46*, *75*). However, *Fagus* is represented in the mountains of Mexico, and species rank (*F. mexicana*) has been given to this population by Martinez (*60*). Since American beech is the only generally recognized native species, it often is simply called "beech". Other common names in local usage include Carolina beech, white beech, red beech, gray beech, and ridge beech (*9*, *44*, *55*).

American beech is found in the East from Canada to Florida, west into Wisconsin in the north and into Oklahoma and Texas in the south (fig. 2). It is a commercial forest species throughout most of its botanical range, although of less importance near the fringes (*87*).

Although beech now is confined to the eastern United States, except for the Mexican population, it once extended as far west as California and probably flourished over most of North America before the glacial period (*6, 9*).

Although beech has long been a favored utility wood in Europe, it has not enjoyed such favor in North America. With the old methods of drying lumber, beech was a bit more difficult to season than the wood of most other species; so in the past, loggers often took the other species, which were plentiful, and left the beech. Yet in all technical qualities beech compares well with the other hardwoods with which it grows, and with modern methods it can be seasoned as effectively as any other wood. In recent years, efforts to increase the utilization of beech have proved that it is a valuable wood for many uses: furniture, flooring, bending, turnings, veneer, plywood, and paper.

Habitat Conditions

CLIMATIC

Within the commercial range of beech the mean annual precipitation varies mostly from 30 to 50 inches (*32, 47, 85*); however, some beech is found in Michigan under a mean precipitation of about 23 inches (*13*), and under about 25 inches in Canada (*45*). Precipitation during the growing season varies from 10 to 18 inches (*85*). Beech is a mesophytic species; its requirement of water for transpiration and growth processes is estimated to be about 10 inches per year, as compared to a 5-inch requirement by some xerophytic oaks and even lower requirements by some pines (*2*).

The growing season for beech varies mostly from 100 to 280 days (*85*); the species is found in one county in Michigan where

Figure 2. — The natural range of American beech.

the growing season is only 92 days (*93*). Mean annual temperatures vary from 40 to 70° F. (*85*). Beech can exist under temperature extremes lower than —44°F. and up to 100°F. (*56, 85*). Relatively high summer temperatures may be unfavorable for beech growth (*25*).

SOILS

Beech occurs mostly on soils of two principal groups: the gray-brown podzolic soils, and the lateritic soils; it is seldom found in limestone valleys (*18*). Although beech may be found on the shallower or less fertile soils if moisture conditions are favorable, it grows best on deep, rich, well-drained, moist soils; those of loamy texture, and those with a high humus content are more favorable than lighter soils (*19, 28, 45, 93*). The largest trees are found in the alluvial bottomlands of the Ohio and the lower Mississippi River valleys, and along the western slopes of the Southern Appalachian Mountains (*19*).

In Indiana, beech was found to be more sensitive to reduced soil moisture than white oak (*Quercus alba*), sugar maple (*Acer saccharum*), American elm (*Ulmus americana*), and slippery elm (*Ulmus rubra*) (*30*).

Although beech will grow on poorly drained sites if not subjected to prolonged flooding (*9*, *68*, *69*), and may grow where the water table is within 6 to 10 inches from the surface (*67*), it is markedly less tolerant of such conditions than red maple (*Acer rubrum*) and sweetgum (*Liquidambar styraciflua*) (*70*). Beech trees on poorly drained sites have shallower root systems than those on better drained sites (*31*).

In a study of effects of flooding in Kentucky, beech was found to be one of the more sensitive species. In summer, beech trees were killed by 2 weeks' submergence of their root crowns. However, an 18-day period of flooding in winter had no apparent adverse effect (*33*).

Timber stands containing considerable numbers of beech occur on soils ranging from pH 4.1 to 6.0 (*36*, *41*, *73*, *96*), but a pH exceeding 7.0 inhibits their growth (*71*).

Beech leaves tend to contain less calcium than those of many other hardwoods, and not much more than is found in pine foliage. Average calcium contents of leaves, in percent of dry weight, have been reported as follows: beech—0.91, white pine—0.69, white oak—1.24, red oak—1.23, sugar maple—1.70, yellow poplar—2.96, and basswood—3.52 (*58*).

PHYSIOGRAPHIC

Beech is found from relatively low elevations in the North up to 6,000 feet in the Southern Appalachians (*9*). Local soil and climatic factors probably determine whether or not beech occurs at the higher elevations. In the Adirondacks of New York, low temperatures and wind keep beech below 3,200 feet; but in the southern mountains on the warmer, south slopes it ranges up to 6,000 feet (*9*, *10*, *36*). Over most of its range, however, beech is more abundant on the cooler and moister north slopes than on south slopes (*5*, *9*, *16*, *41*, *42*, *58*, *69*).

BIOTIC

In its wide range through eastern North America, beech is associated with a large number of other trees. Some of the principal associates are: sugar maple (*Acer saccharum*), yellow birch

(*Betula alleghaniensis*), American basswood (*Tilia americana*), black cherry (*Prunus serotina*), southern magnolia (*Magnolia grandiflora*), eastern white pine (*Pinus strobus*), red spruce (*Picea rubens*), several hickories (*Carya spp.*), and oaks (*Quercus spp.*). Beech is listed in 16 of the cover types recognized by the Society of American Foresters (*77*), and is named as an important component of four types:

Type 25—Sugar maple-beech-yellow birch.
Type 31—Red spruce-sugar maple-beech.
Type 60—Beech-sugar maple.
Type 90—Beech-southern magnolia.

Many animals and birds are associated with beech (*97*); they consume considerable quantities of beech nuts (*27, 59, 88*). The bark of beech may be consumed by beaver (*Castor canadensis*), porcupine (*Erithizon dorsatus*) (*59*), mice (*Peromyscus spp.*), snowshoe hares (*Lepus americanus*), and rabbits (*Sylvilagus transitionalis*) (*34*). Gray squirrels (*Sciurus carolinensis*) in northern Ohio have been observed feeding on beech blossoms, and later on unripe beechnuts in the middle of June (*97*). In the Adirondacks, the writer has observed repeated annual clipping of small beech suckers near the ground by snowshoe hares. This occurs mostly during the winter months.

Beech seldom is severely browsed by white-tailed deer (*Odocoileus virginianus*). When other, more desirable species are available, beech usually is nipped only sparingly (*8, 23, 65, 91*).

Life History

SEEDING HABITS

Flowering and fruiting.—In the Northern and Central States beech flowers appear in late April or early May, when the leaves are about one-third grown; the flowers are monoecious (*11, 75*). Beech nuts require one growing season to mature, ripening between September and November (*86*). Either two or three nuts may be found within a single bur (*35*). The first nuts to fall may be wormy or aborted (*83*). Seed-fall begins after the first

heavy frosts have caused the burs to open (*86*), and usually is completed within a few weeks. Empty burs may remain on the trees through the winter.

Seed production and dissemination.—Beech ordinarily begins to produce seed when 40 to 50 years old (*27*), and may produce large quantities when 40 to 60 years old (*86*). Good beech seed crops may occur at 2- or 3-year intervals (*3*, *24*, *86*); however, intervals of 4 or 5 years have been reported (*18*).

The nuts are borne in an egg-shaped prickly husk, two or three nutlets to a husk. The nut is thin-shelled, shining chestnut-brown, angularly three-sided.

Beech nuts are relatively heavy, and most of them simply drop to the ground under the parent trees. Birds and rodents may carry some seeds short distances from the source, and on steep terrain a few seeds may roll down slopes, but natural dispersal is rather restricted (*2*).

Seed storage.—Because beech seeds are sensitive to drying, they deteriorate unless stored under moist conditions (*2*, *83*). However, seed in wet ground or covered tightly with sodden leaves may decay. In the open, a light covering of litter provides suitable storage conditions (*2*). In nursery culture, beech nuts usually are sown or stratified as soon as possible after collection, but can be stored satisfactorily over winter at 41° F. in sealed containers (*86*).

Size and germination of seed.—Cleaned beech seed averages about 1,600 per pound; there are about 9 pounds of seed per bushel, and 32 pounds of seed per 100 pounds of unextracted burs. Seeds average about 87 percent sound (*86*).

VEGETATIVE REPRODUCTION

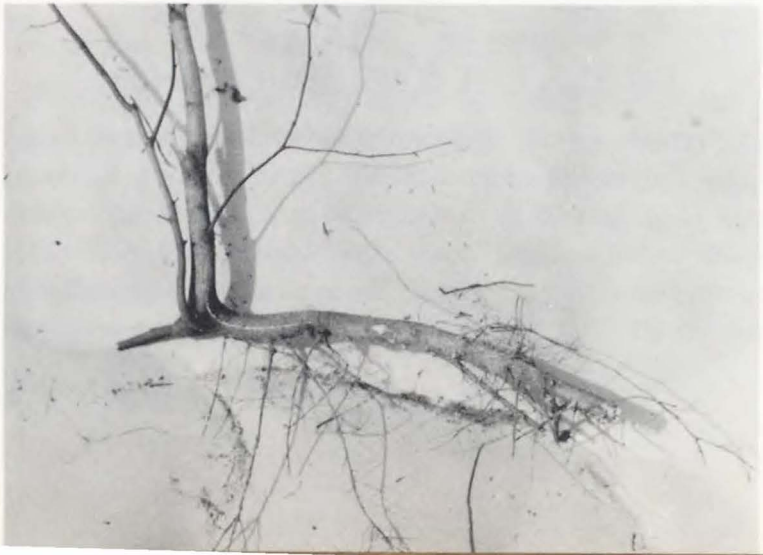
Stump sprouts.—Beech sprouts well from the stumps of young trees, but that ability diminishes after trees reach 4 inches in diameter (*18*). Sprouts from stumps 10 to 15 inches in diameter usually are short-lived and do not attain tree stature (*21*, *29*, *32*). Numerous sprouts may develop on the trunk of beech immediately below a wound (*66*), and from the tops of stumps; here adven-

titious buds develop in callus tissues originating from the cambial region.

Root suckers.—Beech trees may develop root suckers in large numbers. Although suckering seems to be stimulated by injury to the tree or to its roots, suckers often are present where no injury is evident (*57, 66, 74, 92*). From 700 to 900 suckers per acre (7 to 12 per tree), plus about an equal number of beech

Figure 3.—Beech root suckers with no nearby feeding roots, which probably are incapable of becoming independent of the parent tree. This root was more than 40 years old.

Figure 4.—Beech root suckers with feeding roots growing from the parent root nearby. This sucker probably could continue growth independently upon death of the parent tree. Reduced growth of parent root on the side away from the tree (left in this photo) is a common occurrence.



seedlings were tallied under an undisturbed stand of mature beech in the Adirondacks (*74*). Casual observations elsewhere indicate that the number of suckers originating from one tree may greatly exceed the 7 to 12 mentioned above. Harlow and Harrar (*35*) refer to "thickets", composed mostly of root suckers, surrounding old trees.

No information on root-sucker development, other than general observations, has been reported. It is not known to what extent or under what conditions suckers develop root systems that enable them to grow to tree size. The writer has observed feeding roots growing from the parent root near some small suckers, and complete absence of such roots near others (figs. 3 and 4). It seems probable that roots like those shown in figure 4 have the potential to develop into an independent system capable of supporting a growing tree, whereas suckers like those shown in figure 3 appear incapable of becoming independent. Such suckers are essentially parasitic on the parent tree.

The prevailing opinion is that beech root suckers seldom, if ever, develop into desirable forest trees (*34*, *35*, *44*). It is known that sometimes the suckers are ephemeral; Hough, for instance, in a study of the reproduction after cutting a 60-year-old stand of beech, reported that all of the many root suckers died within 4 years (*39*). On the other hand, they may live and grow—perhaps rather slowly—for many years. Illick and Frontz observed a 40-year-old beech stand, said to be of sucker origin, in which the trees averaged 4 inches in diameter and 38 feet tall (*47*). Suckers of comparable diameter have been observed in the Adirondacks (*74*).

Layering.—Beech roots freely in a single year when layered (*83*).

SEEDLING DEVELOPMENT

Establishment.—Beech seeds germinate from early spring to early summer; germination is epigeous and may be slow because of a dormant embryo (*86*). Good germination may occur on either mineral soil or leaf litter (*29*, *78*, *92*). Adequate moisture in the soil or duff is required, but germination is poor on exces-

sively wet sites (*40, 73, 97*). Both germination and survival tend to be better on mor humus than on mull humus (*36, 73, 89*).

Beech seedlings develop better beneath a moderate canopy or in protected small openings than in larger open areas where the surface soil may dry out below the depth of the shallow seedling roots (*32, 82*). Seedlings commonly are found in large numbers beneath even the densest stands (*45, 91*), but their growth is slow under such conditions. In partially open stands, seedlings tend to be more numerous and larger in the openings than in the shade and root zone of standing trees (*81*). Beech reproduction can compete successfully with ferns and raspberries on recently cutover sites (*81*).

Beech seedlings are sensitive to artificial temperatures and photoperiods. Kramer (*54*) showed that dormancy could be broken in spring and growth could be prolonged in fall by providing supplemental light. He suggested that, in nature, decreasing day length probably plays the major role in inducing dormancy in the fall, but may be secondary to temperature in stimulating resumption of growth in the spring. That is, day length probably becomes adequate for growth resumption in the spring before temperatures are high enough for growth to occur; temperature therefore exerts the final control.

In other experiments, beech continued growth all winter under continuous light in a greenhouse, but succumbed later (*52*).

Early growth.—According to one report, height growth of beech seedlings in a nursery averaged 5 inches the first year, and 40 inches in 6 years (*2*). The height of beech seedlings growing in the intense competition of a virgin hemlock-hardwood stand in northern Pennsylvania (*37*) was:

Age (years)	*Total Height (feet)*
6	1
10	2
14	3
17	4
18	4.5
20	5
22	6
25	7

Under less severe competition height growth of wild seedlings probably would be considerably greater than shown above.

However, beech reproduction in the open, as after a clearcutting, does not grow as fast as that of most associated hardwood species. It may be overtopped not only by intolerant and intermediate species, such as white ash, red maple, and the birches, but also by the tolerant sugar maple. Under an overstory, beech reproduction, despite its relatively slow growth, holds a competitive advantage by virtue of its tolerance and its near immunity to deer browsing.

SAPLING STAGE TO MATURITY

Annual growth.—In general, radial growth of beech begins with full expansion of the leaves (*30*, *49*). Beech has a grand period of radial growth which may continue for 80 to 89 days in the Georgia Piedmont (*49*), and for approximately 60 days in Indiana (*30*). According to a study in Connecticut, the annual height growth of beech saplings is completed in about 60 days, 90 percent of it occurring between May 10 and June 10 (*53*).

The period of radial growth appears to be strongly influenced by available soil moisture. Under normal conditions this period may end about the middle of July, but it may be terminated by mid-June if drought occurs (*25*, *30*). Individual trees may continue growth into August and September (*31*, *49*). In dry years annual rings may not form on the basal sections of some beech trees (*84*).

The annual diameter increment of pole and small sawlog size trees averages from around 0.07 to 0.09 inch in undisturbed second-growth stands to 0.15 to 0.19 inch in trees released by partial cuttings (*43*, *93*, *98*, *101*).

Cumulative growth and longevity.—Under optimum conditions beech trees may reach 120 feet in height; however, they generally average 60 to 80 feet (*11*). Some growth data for beech in the Lake States are shown in table 1 (*32*):

Among 12 broadleaved species rated according to their longevity, beech was exceeded only by white oak and sugar maple

Table 1.—*Growth data for American beech in the Lake States*

Age	Total height		D.b.h.		Volume	
	Average	Maximum	Average	Maximum	Average	Maximum
(years)	*Feet*	*Feet*	*Inches*	*Inches*	*Cubic feet*	*Cubic feet*
20	13	19	0.7	1.3	—	—
40	28	35	2.3	3.3	—	—
60	39	48	3.8	5.4	1.0	3.6
80	48	59	5.4	7.5	3.7	8.7
100	57	68	7.1	9.6	7.8	16.5
150	75	83	11.5	14.6	27.0	47.0
200	84	87	15.7	19.1	56.0	89.0
250	88	91	19.9	23.6	95.0	143.0

(*82*). Beeches exceeding 366 years of age have been found in Pennsylvania (*42*). One of the largest beeches of record was 16 feet and 7 inches in circumference at breast height, 75 feet tall, and the crown was 80 feet wide; it grew in New Jersey (*1*). A Carolina beech (*F. grandifolia* var. *caroliniana*) was 12 feet 10 inches in circumference at breast height, and the crown spread was 126 feet (*1*).

Root system.—The root system of a beech tree tends to be shallow where soil moisture and air humidity are ample; roots extend deeper where moisture is less abundant (*32*). According to Moore (*62*), beech roots spread strongly in the humus layer and also grow fairly deep into the mineral soil. Except possibly on shallow soils, the species is comparatively wind-firm (*4, 95*). Root growth has been observed in the Northeast to continue into October (*62*).

Tolerance and climax position.—Beech is very tolerant (*2, 29*). In some parts of the range it is regarded as the most tolerant species (*18, 42, 100*). It may be less tolerant on very poor soils or in very cold climates (*100*).

Figure 5.—The best-formed beech trees usually are found on fertile soils. These beech are among a good stand of sugar maple in the Adirondack Mountains of New York.

In tolerance, beech and the widely associated sugar maple are of about the same order, although locally one species or the other may predominate in the forest understory and there appear to be the more tolerant. Under laboratory conditions Burns (*12*) found that the compensation point (the minimum light intensity required for photosynthesis to balance respiration) was slightly lower for sugar maple than for beech, which implies slightly greater photosynthetic efficiency and tolerance in the maple. However, the validity of the compensation point as a measure of tolerance has been widely questioned.

Branching habits and form.—Beech trees prune themselves nicely in well-stocked stands (*34*). Both site quality and crown competition influence tree form (*34, 82*); with good stocking on favorable sites, a substantial proportion of the trees have narrow, compact crowns and long, clean, straight boles (fig. 5 and fig. 6). Bole taper generally is greater on the poorer sites.

Figure 6.—A log from a well-formed beech tree—long, clean, straight, and sound.

Open-grown trees develop short, thick trunks with large, low, spreading limbs terminating in slender, somewhat drooping branches, forming a broad, round-topped head (*11*).

Beech trees that have been injured or suddenly exposed by cuttings in a stand often develop epicormic branches (fig. 7). In one instance where 65 percent of the basal area of a stand had been cut, 40 percent of the remaining beeches possessed epicormic branches 5 years later, whereas in a similar but uncut stand only 17 percent of the trees had such branches (*38*). Epicormic branch-

ing of beeches has been observed after glaze damage (*80*), and after low-temperature injury (*63*). According to one report on winter injury, subsequent epicormic branching was mainly on trees of 4 inches or less diameter.[1]

The growth characteristics and tolerance of beech help explain its behavior under different cutting practices. Clearcutting commonly results in less beech in the new stand than in the old (*42*, *50*, *51*, *81*, *94*). Under repeated clearcutting on short rotations, as formerly was done in the acid wood industry, beech may almost disappear because in the open its seedlings, suckers, and sprouts are outgrown by the reproduction of almost all associated species (*64*, *81*). In contrast, under light selection cuttings,

[1]Cain, Robert L. Winter killing of beech on the Huntington Forest. Unpublished thesis: State Univ. N. Y. Coll. Forestry, Syracuse. 19 pp., illus. 1942.

Figure 7.—Epicormic branches developed on the bole of this beech tree after the surrounding trees were removed.

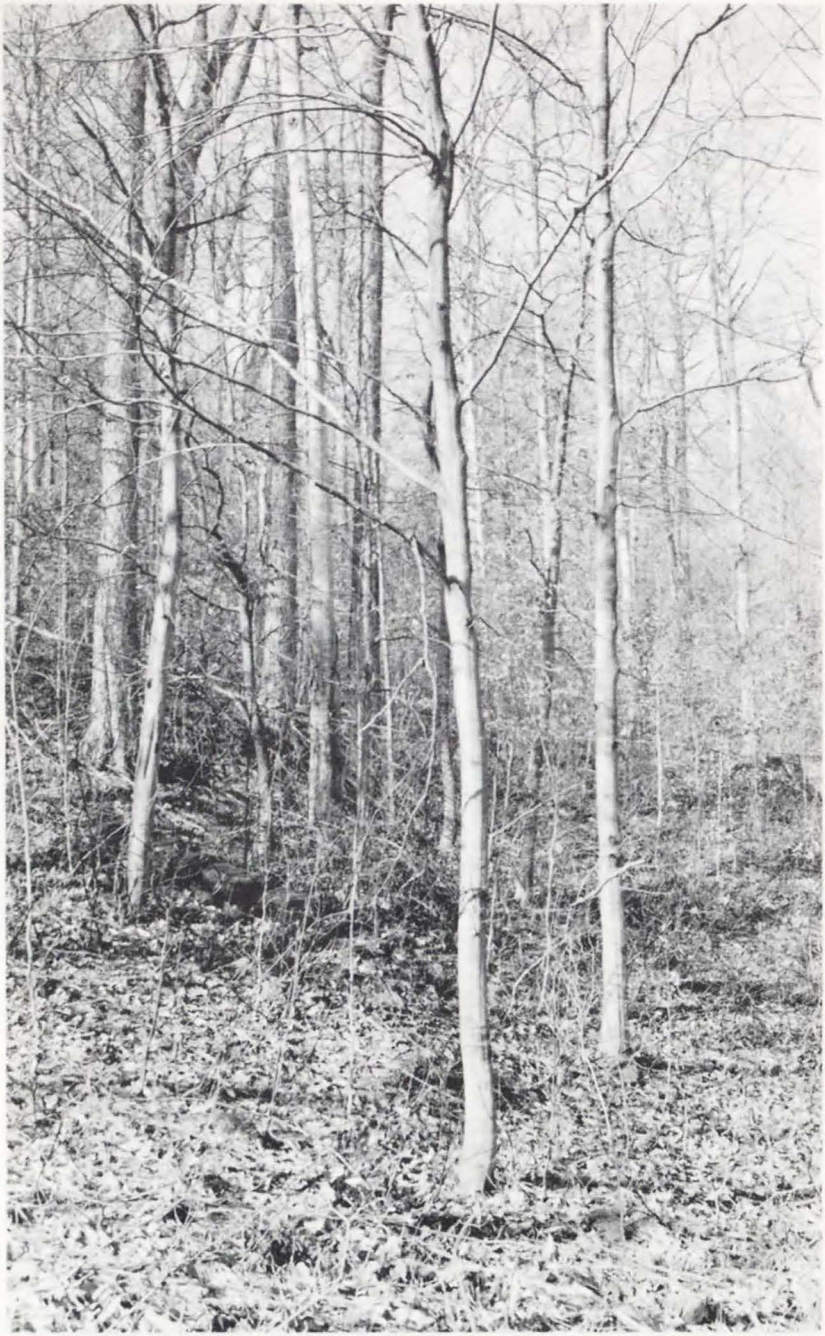


Figure 8.—Beech increases in relative abundance under light selective cutting. This stand was lightly cut 17 and 6 years before the photograph was taken.

the tolerance of beech enables it to increase in relative abundance (fig. 8), whereas less tolerant species decrease. However, the relatively high proportions of beech in many present-day stands are more a result of no management than of silvical characteristics—the beech simply was left when more valuable species were cut.

Beech (and sugar maple) are recognized as climatic climax species in the northern hardwood type of the Northeast, Lake States, and Appalachian Mountains (*2*, *90*). Relict areas of beech in the Southeast suggest that the maple-beech association once was more extensive in that region, but has been replaced by the oak-hickory that formerly was subclimax to it (*90*).

Susceptibility to fire, sun, and winter damage.—With its thin bark and large surface roots, beech is highly vulnerable to fire injury (*34*, *81*). Repeated fires can virtually eliminate beech and its common associates, reverting the cover to a subclimax type—often some combination of aspen (*Populus tremuloides*, *P. grandidentata*), gray birch (*Betula populifolia*), and pin cherry (*Prunus pensylvanica*) (*48*).

Thin bark also is a factor in the susceptibility of beech to sunscald. Trees in undisturbed forest suffer little damage (*7*, *34*), but injury may occur when stands have been opened by cutting, windthrow, or storm breakage (*94*).

Figure 9. — Because of its thin bark, beech is rather vulnerable to damage by fire.

Figure 10. — In northern regions, beech trees sometimes suffer long frost cracks. Ordinarily these do not affect lumber quality.

Beech is subject to occasional foliage damage by late spring frosts. In regions of low winter temperatures, long frost cracks (fig. 10) often occur in the tree trunks; some of the cracks are superficial, and some extend deep into the bole (*34*). Even more serious injury may follow extremely low temperatures under certain circumstances. In the Northeast, trees have been killed or badly damaged by temperatures of —40° to —50° F. when preceded by severe drought (*20*, *63*, *79*).

The susceptibility of beech to glaze-storm breakage is no greater than that of most associated hardwoods, and may run somewhat less than the average for a mixed stand (*17*, *26*, *80*). However, beech is highly susceptible to the sap-rotting fungi that find entrance in large broken branches and sun-scald wounds (*14*, *80*). Wounds of all kinds—from artificial pruning, from logging injuries, or from storm damage—heal comparatively slowly (*61*, *83*, *99*).

Diseases & Insects

Of the fungi that infect beech, *Nectria coccinea* var. *faginata* is the most important. It commonly gains entrance following attacks of the beech scale (*Cryptococcus fagi*); the two organisms constitute the so-called scale-*Nectria* complex, the fungus partner of which produces the bark disease (fig. 11) that is causing extensive mortality of beech in parts of New York, New England, and adjacent Canada (*7, 34, 76*). As much as 50 percent of the beech trees in some localities have been killed (*22, 34*).

The other fungal pathogens of importance are rot producers, among which may be mentioned *Fomes applanatus*, *F. connatus*, *F. fomentarius*, *F. igniarius*, *Polyporus glomeratus*, and *Ustulina vulgaris* (*7, 15, 34, 76*). The shoestring fungus (*Armillaria mellea*) also is commonly found on beech, but is regarded as a secondary invader of weakened trees, not a primary pathogen (*9*).

The bark of beech in the Adirondacks frequently is marked by smooth dark blotches caused by a lichen, *Trypethelium virem*. In

Figure 11.—A severe infection of the beech bark disease on a beech tree. This condition is brought about by the double attack of a scale insect and a fungus disease.

its later stages this lichen causes roughening of the bark, but it appears to be superficial and probably is harmless.[2]

The most serious insect pest of beech is the previously mentioned beech scale. Although the scale seldom is a direct cause of beech mortality, it is associated with considerable mortality in its role of predisposing agent for infection by the *Nectria* fungus.

Figure 12.—The fungus conk indicates that this beech tree is infected with a rot-producing disease.

The most damaging beech defoliator is the saddled prominent (*Heterocampa guttivitta*). Other defoliators that occasionally or locally may do severe damage are the gypsy moth (*Porthetria dispar*) and Bruce's spanworm (*Operophtera bruceata*) (*22*).

[2]Waterman, Alma M. Personal correspondence.

Racial Variation

The existence of races in beech has been postulated occasionally in the literature, but without supporting evidence (*70*, *86*). Apparently the only intensive studies of raciation in beech are those of W. H. Camp, who has not yet published his findings; some second-hand information is supplied by Braun (*9*). According to Braun, Camp has distinguished three races or variants of beech in the United States, plus a fourth in the mountains of Mexico that has been given species rank (*F. mexicana*) by Martinez (*60*). The three U. S. races have been designated as gray, white, and red beeches; and *F. mexicana* is said to be very close to our gray beech.

Geographically, the three U. S. races overlap somewhat and introgressions probably occur. Gray beech occurs at high elevations from Tennessee and North Carolina, northward along the crests of the mountains, coming nearly to sea-level in Nova Scotia; it marks the northern limits of our beech population from Nova Scotia westward to the Great Lakes region. White beech occurs on the southern coastal plains and low hills, extending northward along the coastal plain and Piedmont to about the glacial boundary; it also is very common in the interior. Red beech occurs at mid-elevations in the southern Appalachians and in the hemlock-white pine-northern hardwoods region.

A single "rough-barked" beech tree has been reported from southwestern Mississippi (*72*). Apparently this tree is distinctive in appearance; whether it represents an extreme variation or a mutant has not been determined.

One variety in addition to the species type is recognized; this is Carolina beech (*F. grandifolia* var. *caroliniana*) (*55*, *75*). It is widely distributed in the Southern States, north to New Jersey and Ohio, ranging from bottomlands and swamp borders up to 4,000 feet in the mountains.

Literature Cited

(1) American Forestry Association.
1951. Report on American big trees. Part I. Amer. Forests 57: 25-26.

(2) Baker, F. S.
1950. Principles of silviculture. 413 pp., illus. New York.

(3) Baldwin, Henry I.
1942. Forest tree seed of the north temperate regions with special reference to North America. 240 pp., illus. Waltham, Mass.

(4) Behre, C. E.
1921. A study of windfall in the Adirondacks. Jour. Forestry 19: 632-637.

(5) Belyea, Harold C.
1922. A suggestion for forest regions and forest types as a basis of management in New York State. Jour. Forestry 20: 854-868.

(6) Berry, E. W.
1916. Notes on the ancestry of the beech. Plant World 19: 68-77, illus.

(7) Boyce, J. S.
1938. Forest pathology. 599 pp., illus. New York.

(8) Bramble, W. C., and Goddard, M. K.
1953. Seasonal browsing of woody plants by white-tailed deer in the ridge and valley section of central Pennsylvania. Jour. Forestry 51: 815-819, illus.

(9) Braun, E. L.
1950. Deciduous forests of eastern North America. 596 pp., illus. Philadelphia and Toronto.

(10) Brown, Dalton M.
1941. The vegetation of Roan Mountain: a phytosociological and successional study. Ecol. Monog. 11: 61-97.

(11) Brown, H. P.
1922. Trees of New York State, native and naturalized. N.Y. State Univ. Col. Forestry Tech. Pub. 15. 401 pp., illus. Syracuse.

(12) Burns, G. P.
1923. Studies in tolerance of New England trees. IV. Minimum light requirements referred to a definite standard. Vt. Agr. Expt. Sta. Bul. 235. 32 pp.

(13) Cain, Stanley A.
1935. Studies on virgin hardwood forest: III: Warren's woods, a beech-maple climax forest in Berrien County, Michigan. Ecology 16: 500-513, illus.

(14) Campbell, W. A.
1937. Decay hazard resulting from ice damage to northern hardwoods. Jour. Forestry 35: 1156-1158.

(15) Campbell, W. A., Spaulding, P.
1942. Stand improvement of northern hardwoods in relation to diseases in the northeast. U. S. Forest Serv., Allegheny Forest Expt. Sta. Occas. Paper 5, 25 pp., illus.

(16) Cantlon, John E.
1953. Vegetation and microclimates on north and south slopes of Cushetunk Mountain, New Jersey. Ecol. Monog. 23: 241-270, illus.

(17) Carvell, K. L., Tryone, E. H., and True, R. P.
1957. Effects of glaze on the development of Appalachian hardwoods. Jour. Forestry 55: 130-132, illus.

(18) Cheyney, E. G.
1942. American silvics and silviculture. 472 pp., illus. Minneapolis, Minn.

(19) Collingwood, G. H.
1945. Knowing your trees. 213 pp., illus. Amer. Forestry Assoc., Washington, D. C.

(20) Cope, J. A.
1935. Winter injury to hardwoods in 1933-1934. Jour. Forestry 33: 939-940.

(21) Cope, J. A.
1939. A hardwood record. Jour. Forestry 37: 495-497, illus.

(22) Craighead, F. C.
1950. INSECT ENEMIES OF EASTERN FORESTS. U. S. Dept. Agr. Misc. Publ. 657. 679 pp., illus.

(23) Curtis, R. O., and Rushmore, F. M.
1958. SOME EFFECTS OF STAND DENSITY AND DEER BROWSING ON REPRODUCTION IN AN ADIRONDACK HARDWOOD STAND. Jour. Forestry 56: 116-121, illus.

(24) Deen, J. L.
1936. SILVICULTURE CHARACTERISTICS OF AMERICAN TREES. 99 pp. Philadelphia.

(25) Diller, Oliver D.
1935. THE RELATION OF TEMPERATURE AND PRECIPITATION TO THE GROWTH OF BEECH IN NORTHERN INDIANA. Ecology 16: 72-81, illus.

(26) Downs, Albert A.
1938. GLAZE DAMAGE IN THE BIRCH-BEECH-MAPLE-HEMLOCK TYPE OF PENNSYLVANIA AND NEW YORK. Jour. Forestry 36: 63-70, illus.

(27) Edminster, Frank C.
1947. THE RUFFED GROUSE — ITS LIFE STORY, ECOLOGY AND MANAGEMENT. 385 pp., illus. New York.

(28) Elliott, J. C.
1953. COMPOSITION OF UPLAND SECOND GROWTH HARDWOOD STANDS IN THE TENSION ZONE OF MICHIGAN AS AFFECTED BY SOILS AND MAN. Ecol. Monog. 23: 271-288, illus.

(29) Eyre, F. H. and Zillgitt, W. M.
1953. PARTIAL CUTTINGS IN NORTHERN HARDWOODS OF THE LAKE STATES. Twenty-year experimental results. U. S. Dept. Agr. Tech. Bul. 1076. 124 pp., illus.

(30) Friesner, R. C.
1952. DENDROMETER STUDIES OF FIVE SPECIES OF BROADLEAF TREES IN INDIANA. Butler Univ. Bot. Stud. 5: 160-172, illus.

(31) Fritts, H. C.
1956. RADIAL GROWTH OF BEECH AND SOIL MOISTURE IN A CENTRAL OHIO FOREST DURING THE GROWING SEASON OF 1952. Ohio Jour. Sci. 56: 17-28, illus.

(32) Frothingham, E. H.
1915. THE NORTHERN HARDWOOD FOREST: ITS COMPOSITION, GROWTH AND MANAGEMENT. U. S. Dept. Agr. Bul. 285. 47 pp., illus.

(33) Hall, T. F. and Smith, G. E.
1955. EFFECTS OF FLOODING ON WOODY PLANTS, WEST SANDY DEWATERING PROJECT, KENTUCKY RESERVOIR. Jour. Forestry 53: 281-285, illus.

(34) Hamilton, Lawrence S.
1955. SILVICULTURAL CHARACTERISTICS OF AMERICAN BEECH. U. S. Forest Serv. Northeast. Forest Expt. Sta. and Northeast. Tech. Com. Util. Beech, Beech Util. Ser. 13. 39 pp., illus.

(35) Harlow, W. M., and Harrar, E. S.
1941. TEXTBOOK OF DENDROLOGY. 542 pp., illus. New York and London.

(36) Heimburger, Carl C.
1934. FOREST-TYPE STUDIES IN THE ADIRONDACK REGION. Cornell Univ. Agr. Expt. Sta. Memoir 165. 122 pp., illus. Ithaca.

(37) Hough, A. F.
1936. HEIGHT GROWTH OF HEMLOCK AND HARDWOOD SEEDLINGS IN A VIRGIN STAND ON EAST TIONESTA CREEK. U.S. Forest Serv. Allegheny Forest Expt. Sta. Tech. Note 12. 2 pp., illus.

(38) Hough, A. F.
1936. EPICORMIC BRANCHING OF ALLEGHENY HARDWOODS. U. S. Forest Serv. Allegheny Forest Expt. Sta. Tech. Note 10. 2 pp., illus.

(39) Hough, A. F.
1937. A STUDY OF NATURAL TREE REPRODUCTION IN THE BEECH-BIRCH-MAPLE-HEMLOCK TYPE. Jour. Forestry 35: 376-378.

(40) Hough, A. F.
1942. SOILS IN A VIRGIN HEMLOCK-BEECH FOREST ON THE NORTHERN ALLEGHENY PLATEAU. Soil Sci. 54: 335-341, illus.

(41) Hough, A. F.
1943. SOIL FACTORS AND STAND HISTORY IN A VIRGIN FOREST VALLEY ON THE NORTHERN ALLEGHENY PLATEAU. Soil Sci. 56: 19-28, illus.

(42) Hough, A. F., and Forbes, R. D.
1943. THE ECOLOGY AND SILVICS OF FORESTS IN THE HIGH PLATEAUS OF PENNSYLVA-

NIA. Ecol. Monog. 13: 299-320, illus.

(43) Hough, A. F., and Taylor, R. F.
1946. RESPONSE OF ALLEGHENY NORTHERN HARDWOODS TO PARTIAL CUTTING. Jour. Forestry 44: 30-38, illus.

(44) Hoyle, R. J., Henderson, H. L. Blew, J. O. and Brown, N. C.
1940. BEECH, ITS PRODUCTION PROPERTIES, USES, SEASONING AND TREATMENT. N. Y. State Univ. Coll. Forestry Tech. Pub. 51. 76 pp., illus. Syracuse.

(45) Hutchinson, A. H.
1918. LIMITING FACTORS IN RELATION TO SPECIFIC RANGES OF TOLERANCE OF FOREST TREES. Bot. Gaz. 66: 465-493, illus.

(46) Illick, J. S.
1922. THE BEECHES. Amer. Forestry 28: 546-551, illus.

(47) Illick, J. S., and Frontz, L.
1928. THE BEECH - BIRCH - MAPLE FOREST TYPE IN PENNSYLVANIA. Pa. Dept. Forest and Waters Bul. 46. 40 pp., illus.

(48) Ineson, F. A., and Ferree, M. J.
1948. THE ANTHRACITE FOREST REGION: A PROBLEM AREA. U. S. Dept. Agr. Misc. Pub. 648. 71 pp., illus.

(49) Jackson, L. W. R.
1952. RADIAL GROWTH OF FOREST TREES IN THE GEORGIA PIEDMONT. Ecology 33: 336-341, illus.

(50) Jensen, Victor S.
1943. SUGGESTIONS FOR THE MANAGEMENT OF NORTHERN HARDWOOD STANDS IN THE NORTHEAST. Jour. Forestry 41: 180-185, illus.

(51) Jensen, Victor S., and Wilson, Jr., R. W.
1951. MOWING OF NORTHERN HARDWOOD REPRODUCTION NOT PROFITABLE. U. S. Forest Serv. Northeast. Forest Expt. Sta. Res. Note 3, 4 pp.

(52) Jester, J. R., and Kramer, P. J.
1939. THE EFFECT OF LENGTH OF DAY ON THE HEIGHT GROWTH OF CERTAIN FOREST TREE SEEDLINGS. Jour. Forestry 37: 796 803, illus.

(53) Kienholz, Raymond.
1941. SEASONAL COURSE OF HEIGHT GROWTH IN SOME HARDWOODS IN CONNECTICUT. Ecology 22: 249-258, illus.

(54) Kramer, Paul J.
1936. EFFECT OF VARIATION IN LENGTH OF DAY ON GROWTH AND DORMANCY OF TREES. Plant Physiol. 11: 127-137, illus.

(55) Little, Elbert L., Jr.
1953. CHECK LIST OF NATIVE AND NATURALIZED TREES OF THE UNITED STATES (including Alaska). U. S. Dept. Agr., Agr. Handbook 41. 472 pp., illus.

(56) Livingston, Burton E., and Shreve, Forrest.
1921. THE DISTRIBUTION OF VEGETATION IN THE UNITED STATES, AS RELATED TO CLIMATIC CONDITIONS. Carnegie Inst. Pub. 284. 590 pp., illus. Washington.

(57) Lutz, H. J.
1930. EFFECTS OF CATTLE GRAZING ON VEGETATION OF A VIRGIN FOREST IN NORTHWESTERN PENNSYLVANIA. Jour. Agr. Res. 41: 561-570, illus.

(58) Lutz, H. J., and Chandler, R. F.
1946. FOREST SOILS. 514 pp., illus. New York and London.

(59) Martin, A. C., Zim, H. and Nelson A. L.
1951. AMERICAN WILDLIFE AND PLANTS. 500 pp. New York, Toronto and London.

(60) Martinez, Maximino.
1940. UNA NUEVA SPECIE FORESTAL (*Fagus mexicana* sp. nova). An. del Inst. Biol. de Mexico 11: 85-89.

(61) McQuilkin, W. E.
1950. EFFECTS OF SOME GROWTH REGULATORS AND DRESSINGS ON THE HEALING OF TREE WOUNDS. Jour. Forestry 48: 423-428.

(62) Moore, Barrington.
1922. HUMUS AND ROOT SYSTEMS IN CERTAIN NORTHEASTERN FORESTS IN RELATION TO REPRODUCTION AND COMPETITION. Jour. Forestry 20: 233-254.

(63) Nash, Robley W.
1943. WINTER KILLING OF HARDWOODS. Jour. Forestry 41: 841-842.

(64) Ostorm, E. C.
1938. CLEAR CUTTING OF YOUNG NORTHERN HARDWOOD STANDS. Jour. Forestry 36: 44-49.

(65) Pearce, John.
1937. THE EFFECT OF DEER BROWSING ON CERTAIN WESTERN ADIRONDACK FOREST TYPES. Roosevelt Wildlife Forest Expt. Sta. Bul. 7 (1):61 pp., illus. N. Y. State Coll. Forestry, Syracuse, N. Y.

(66) Plice, M. J., and Hedden G. W.
1931. SELECTIVE GIRDLING OF HARDWOODS TO RELEASE YOUNG GROWTH OF CONIFERS. Jour. Forestry 29: 32-40, illus.

(67) Potzger, J. E.
1934. A NOTABLE CASE OF BOG FORMATION. Amer. Midland Nat. 15: 567-580, illus.

(68) Potzger, J. E., Friesner, R. C. and Keller, C. O.
1942. PHYTOSOCIOLOGY OF THE COX WOODS: A REMNANT OF FOREST PRIMEVAL IN ORANGE COUNTY, INDIANA. Butler Univ. Bot. Stud. 5: 190-221.

(69) Potzger, J. E., and Chandler L.
1950. BEECH IN THE FORESTS ABOUT LAUGHERY CREEK VALLEY. Ind. Acad. Sci. Proc. 59: 82-94, illus.

(70) Potzger, J. E., and Liming, A. N.
1953. SECONDARY SUCCESSION IN STANDS OF RED MAPLE-SWEET GUM-BEECH FOREST IN RIPLEY COUNTY, INDIANA. Butler Univ. Bot. Stud. 11: 50-59.

(71) Reynolds, Wm., and Potzger, J. E.
1950. DISTRIBUTION OF *Quercus muhlenbergii* IN INDIANA. Butler Univ. Bot. Stud. 10: 71-79.

(72) Rice, H. P.
1948. A ROUGH-BARKED AMERICAN BEECH. Jour. Forestry 46: 48, illus.

(73) Romell, L. G., and Heiberg, S. O.
1931. TYPES OF HUMUS LAYER IN THE FORESTS OF NORTHEASTERN UNITED STATES. Ecology 12: 567-608.

(74) Rushmore, F. M.
1956. BEECH ROOT SPROUTS CAN BE DAMAGED BY SODIUM ARSENITE TREATMENT OF PARENT TREE. U. S. Forest Serv. Northeast. Forest Expt. Sta., Forest Res. Note 57. 4 pp.

(75) Sargent, Charles Sprague.
1933. MANUAL OF THE TREES OF NORTH AMERICA. Ed. 2, 910 pp., illus. Boston and New York.

(76) Society of American Foresters, New England Section.
1952. IMPORTANT TREE PESTS OF THE NORTHEAST. 191 pp., illus. Concord, N. H.

(77) Society of American Foresters.
1954. FOREST COVER TYPES OF NORTH AMERICA. 67 pp., illus. Washington, D. C.

(78) Sowers, D. W., et al.
1956. SOME FACTORS AFFECTING MANAGEMENT OF CONIFERS AND HARDWOODS IN THE ALLEGHENY REGION. Jour. Forestry 54: 563-567.

(79) Spaulding, Perley.
1946. SUSCEPTIBILITY OF BEECH TO DROUGHT AND ADVERSE WINTER CONDITIONS. Jour. Forestry 44: 377.

(80) Spaulding, Perley, and Bratton, A. W.
1946. DECAY FOLLOWING GLAZE STORM DAMAGE IN WOODLANDS OF CENTRAL NEW YORK. Jour. Forestry 44: 515-519, illus.

(81) Spring, S. N.
1922. STUDIES IN REPRODUCTION —THE ADIRONDACK HARDWOOD TYPE. Jour. Forestry 20: 571-580.

(82) Toumey, J. W., and Korstian, C. F.
1947. FOUNDATIONS OF SILVICULTURE UPON AN ECOLOGICAL BASIS. 468 pp., illus. New York and London.

(83) Toumey, J. W., and Korstian, C. F.
1952. SEEDING AND PLANTING IN THE PRACTICE OF FORESTRY. 520 pp., illus. New York and London.

(84) Turberville, H. W., and Hough, A. F.
1939. ERRORS IN AGE COUNTS OF SUPPRESSED TREES. Jour. Forestry 37: 417-418.

(85) United States Department of Agriculture.
1941. CLIMATE AND MAN. U. S. Dept. Agr. Yearbook 1941. 1248 pp., illus.

(86) United States Forest Service.
1948. WOODY-PLANT SEED MANUAL. U. S. Dept. Agr. Misc. Pub. 654. 416 pp., illus.

(87) United States Forest Service.
1958. TIMBER RESOURCES FOR AMERICA'S FUTURE. U. S. Dept. Agr. Forest Resource Rpt. 14. 713 pp., illus.

(88) Van Dersal, W. R.
1939. NATIVE WOODY PLANTS OF THE UNITED STATES, THEIR EROSION - CONTROL AND WILDLIFE VALUES. U. S. Dept. Agr. Misc. Pub. 303. 362 pp.

(89) Ward, Richard T.
1956. THE BEECH FOREST OF WISCONSIN. — CHANGES IN FOREST COMPOSITION AND THE NATURE OF THE BEECH BORDER. Ecology 37: 407-419, illus.

(90) Weaver, J. E., and Clements, F. E.
1938. PLANT ECOLOGY. 601 pp., illus. New York and London.

(91) Webb, W. L., King, R. T. and Patric, E. F.
1956. EFFECT OF WHITE - TAILED DEER ON A MATURE NORTHERN HARDWOOD FOREST. Jour. Forestry 54: 391-398, illus.

(92) Westveld, Marinus.
1931. REPRODUCTION ON PULPWOOD LANDS IN THE NORTHEAST. U. S. Dept. Agr. Tech. Bul. 223. 52 pp., illus.

(93) Westveld, R. H.
1933. THE RELATION OF CERTAIN SOIL CHARACTERISTICS TO FOREST GROWTH AND COMPOSITION IN THE NORTHERN HARDWOOD FOREST OF NORTHERN MICHIGAN. Mich. Agr. Expt. Sta. Tech. Bul. 135. 51 pp.

(94) Westveld, R. H.
1949. APPLIED SILVICULTURE IN THE UNITED STATES. 590 pp., illus. New York and London.

(95) Westveld, R. H., and Peck, R. H.
1951. FORESTRY IN FARM MANAGEMENT. 340 pp. New York and London.

(96) Wilde, S. A., Wilson, F. G. and White, D. P.
1949. SOILS OF WISCONSIN IN RELATION TO SILVICULTURE. Wis. Conserv. Dept. Pub. 525-49. 171 pp., illus.

(97) Williams, A. B.
1936. THE COMPOSITION AND DYNAMICS OF A BEECH-MAPLE CLIMAX COMMUNITY. Ecol. Monog. 6: 317-408.

(98) Wilson, Robert W., Jr.
1953. HOW SECOND-GROWTH NORTHERN HARDWOODS DEVELOP AFTER THINNING. U. S. Forest Serv. Northeast. Forest Expt. Sta., Sta. Paper 62. 12 pp., illus.

(99) Zeedyk, W. D., and Hough, A. F.
1958. PRUNING ALLEGHENY HARDWOODS. U. S. Forest Serv. Northeast. Forest Expt. Sta., Sta. Paper 102. 14 pp., illus.

(100) Zon, Raphael, and Graves, H. S.
1911. LIGHT IN RELATION TO TREE GROWTH. U. S. Forest Serv. Bul. 92. 59 pp.

(101) Zon, Raphael, and Scholtz, H. F.
1929. HOW FAST DO NORTHERN HARDWOODS GROW? Wis. Agr. Expt. Sta. Res. Bul. 88. 34 pp.

These Silvical Papers...

This is one of a series of 15 silvical papers to be published by the Northeastern Forest Experiment Station. The series will include papers on the following species:

*Green ash
*White ash
*Beech
*Paper birch
*Sweet birch
*Yellow birch
*Black cherry
*Red maple
*Balsam fir
*Red spruce
*Eastern hemlock
Eastern white pine
*Pitch pine
*Virginia pine
*Atlantic white-cedar

*Already published.

WOOD · WATER · FORAGE ·
WILDLIFE · RECREATION
FOREST SERVICE
US
DEPARTMENT OF AGRICULTURE